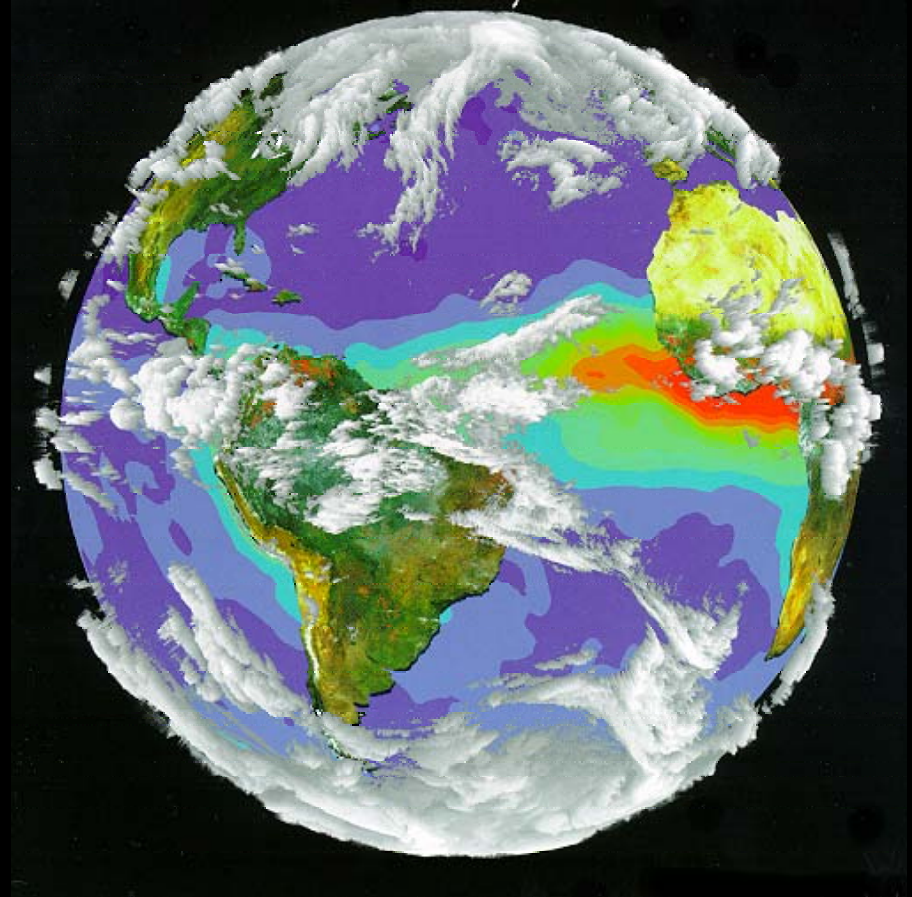


Earth Science Enterprise

The End to End Challenge: Science for Society

**Roger L. King, Ph.D., P.E.
Chief Technologist
Office of Earth Science
Applications Division**



***“Accelerating the realization of economic and societal benefits
from Earth science, information, and technology ...”***



The NASA Vision

To improve life here,
To extend life to there,
To find life beyond.

The NASA Mission

To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
... as only NASA can.



Beyond Scientific Exploration...serving Society

Global Change

IPCC CCRI
NRC NCCTI
USGCRP WMO

Advanced Weather Prediction

NRC NOAA DOD

Natural Hazards

Nat'l. Hazards Ctr
NRC Roundtable
SESWG ...

Earth Science Enterprise

Mission: Focus on weather, climate, and natural hazards

Science

Applications

Education

Technology & Missions

Earth System Knowledge

Operational Imperatives

Federal Local
State Tribal
International
Private Sector

Earth Science Education
K-16 & Beyond

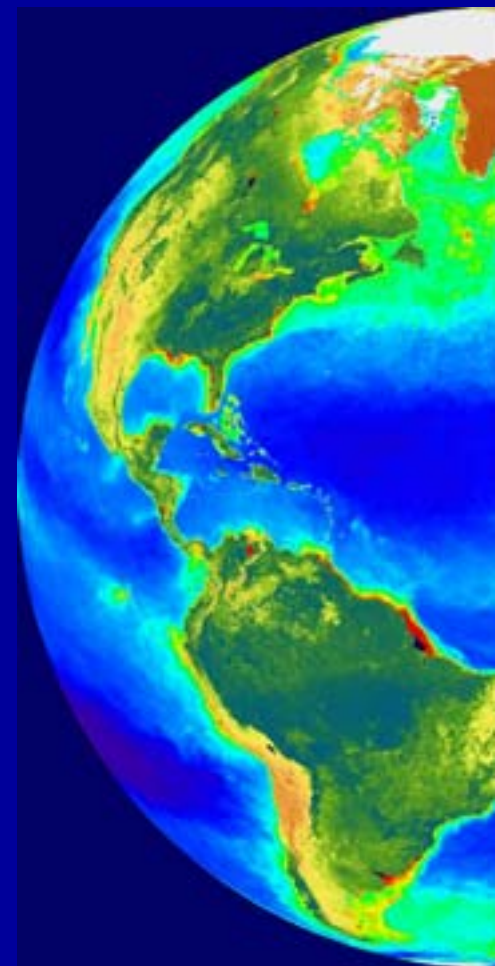


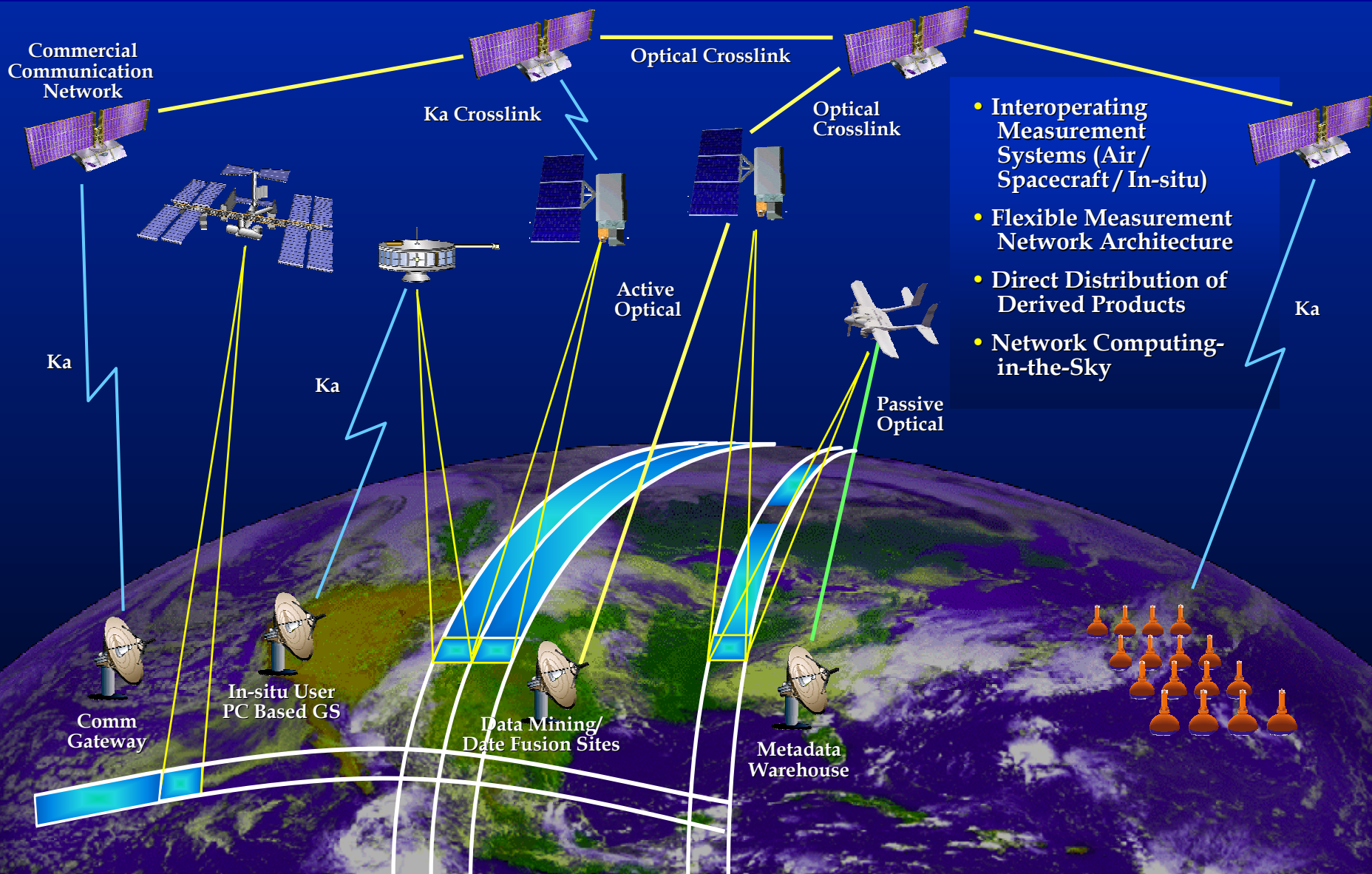


Serving Societal Needs Requires Scientific Understanding

How is the Earth Changing and What Are the Consequences for Life on Earth?

- **How is the global Earth system changing?**
- **What are the primary causes of change in the Earth system?**
- **How does the Earth system respond to natural and human-induced changes?**
- **What are the consequences of changes in the Earth system for human civilization?**
- **How well can we predict future changes to the Earth system?**







Earth Science Modeling Framework

19 major Earth system modeling components

All compliant by April '04

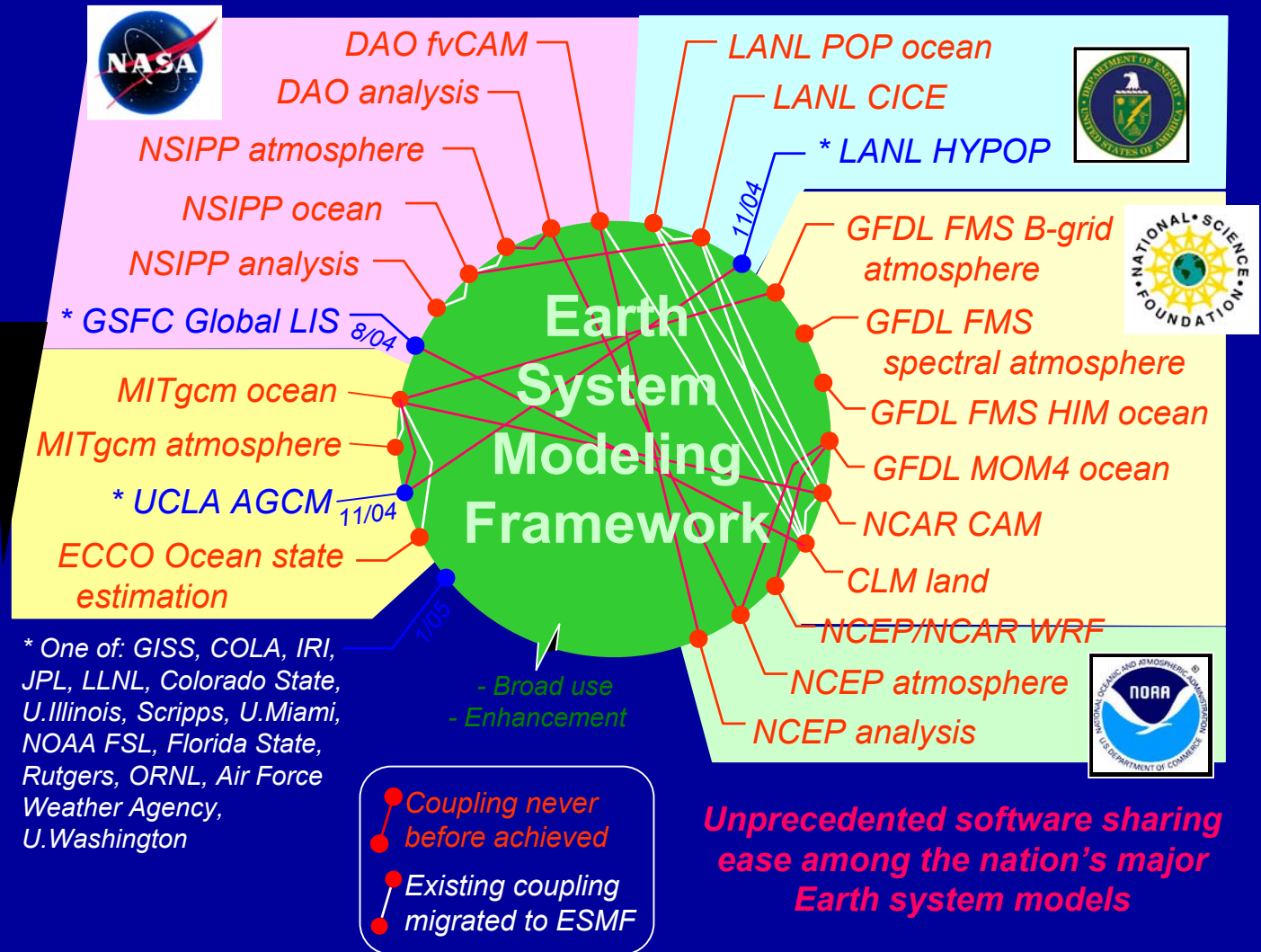
30 ESMF applications

15 research and operational

8 entirely new

7 synthetic samples

* Early adopters of the ESMF





Educating for the End-to-End Information Flow

Petabytes 10^{15}

Multi-platform, multi-parameter, high spatial and temporal resolution, remote & in-situ sensing

Calibration,
Transformation To
Characterized
Geophysical Parameters

Terabytes 10^{12}

Interaction Between
Modeling/Forecasting
and Observation
Systems

Gigabytes 10^9

Interactive
Dissemination

Predictions

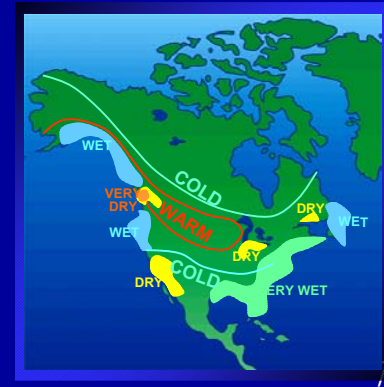
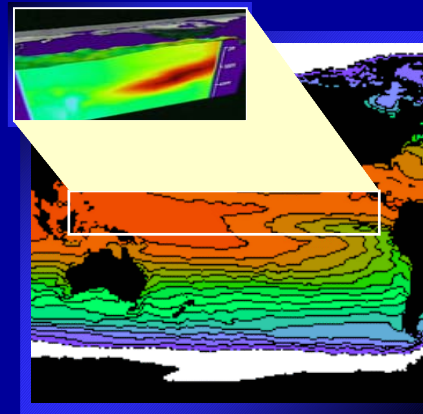
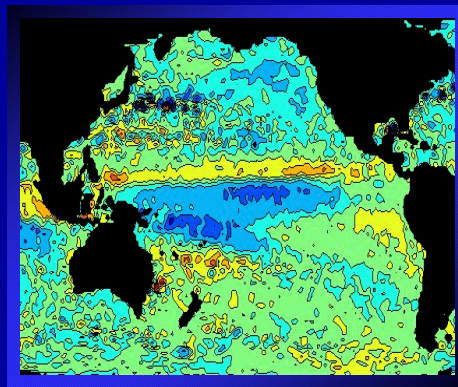
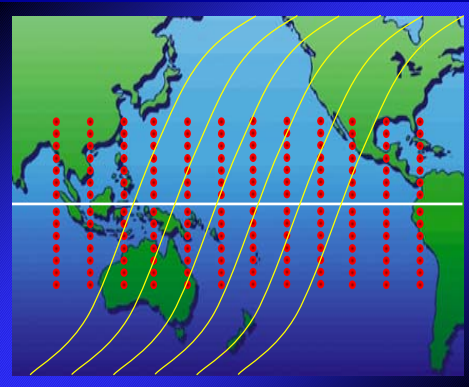
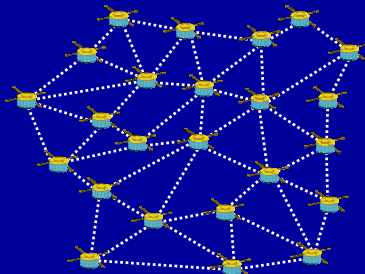
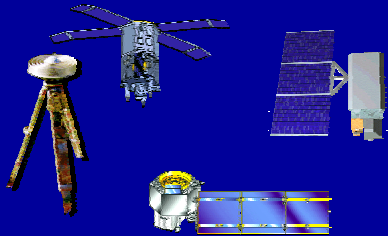
Megabytes 10^6

Advanced Sensors

Data Processing & Analysis

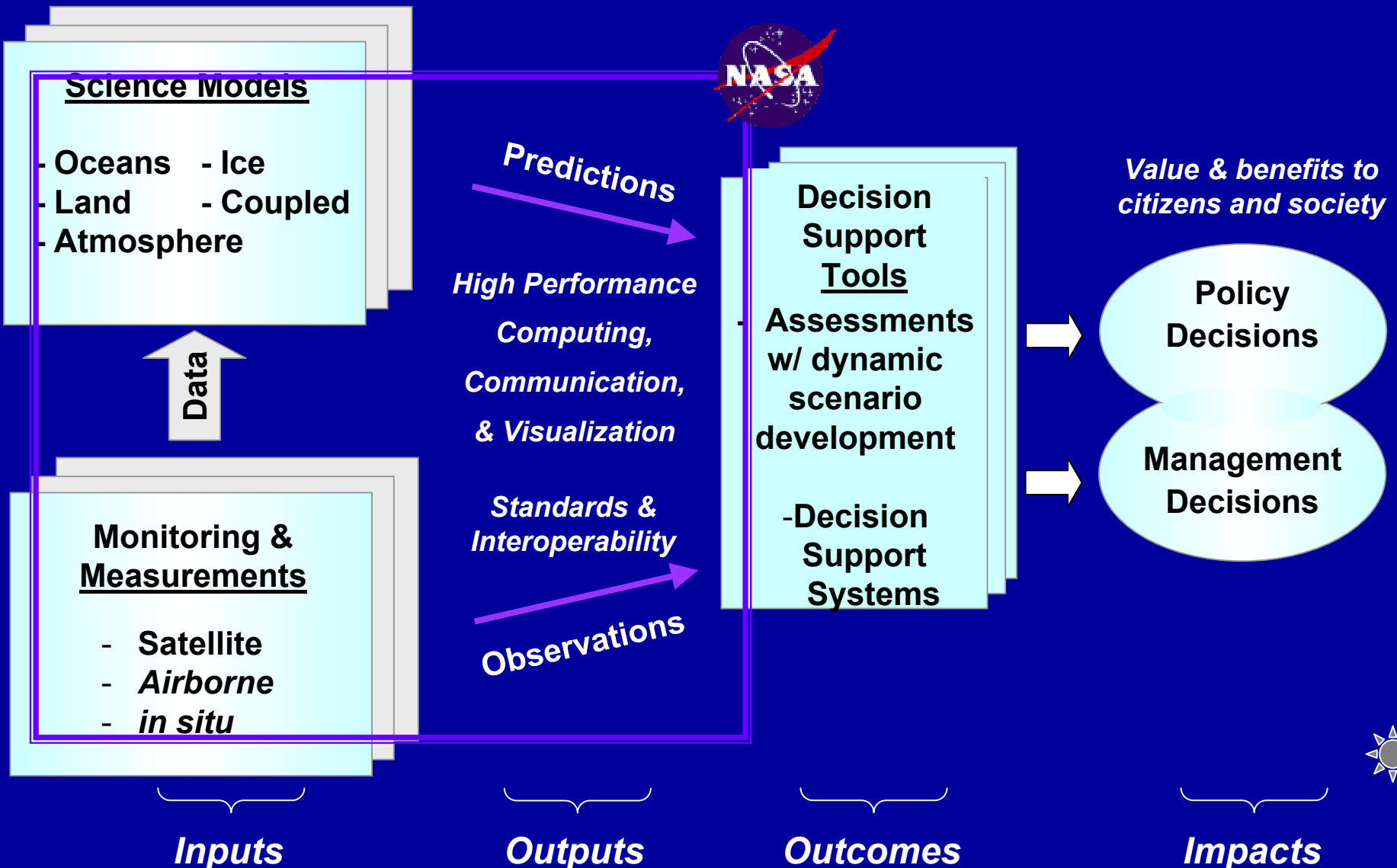
**Information
Synthesis**

Access to Knowledge





Solutions: Science to Decision Support





Applications of National Priority



Carbon Management



Public Health



Energy Forecasting



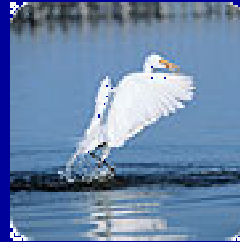
Aviation Safety



Water Management



Homeland Security



Coastal Management



Disaster Preparedness



Agricultural Efficiency



Invasive Species



Community Growth

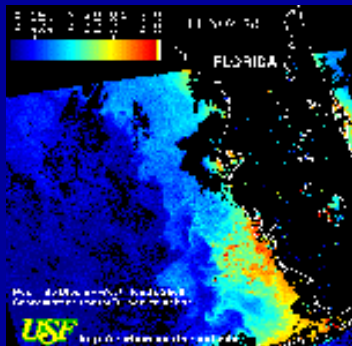


Air Quality

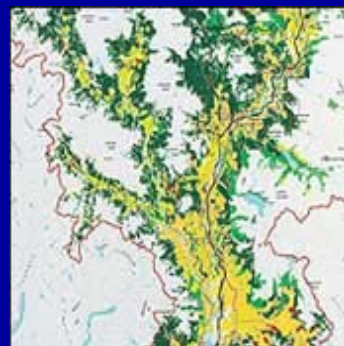




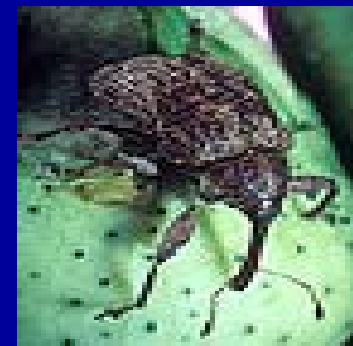
Decision Support Systems



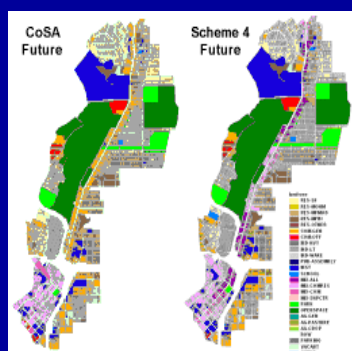
**Coastal Management:
HAB Forecast**



**Water Management:
AWARDS**



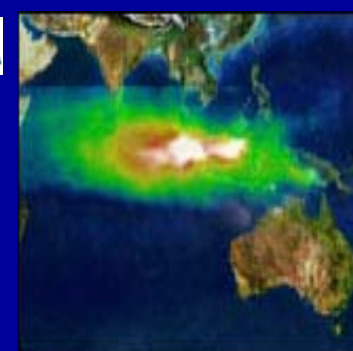
**Invasive Species:
NBII/NISC/CBI**



**Community Growth:
Urban Growth DSS**



**Agricultural:
FAS Forecast**



**Air Quality:
CMAQ/Models-3**





Define Partner Specifications

Assess against existing assets

What missions or ground systems will provide these measurements?

What models or computational technologies are available?

What information systems are necessary?

If not available, assess need & priority.

Translate specs into results

Reverse engr

What measurements are important and why?

What model outputs are important and why?

Reverse engr



Leverage agency research

Decision Support Systems

Assessments

Workforce Development

Outreach

Develop specifications that can improve socioeconomic benefits.

Process flow



US National Air Quality Policy



US Environmental Protection Agency (EPA)

- EPA sets health-based standards for multiple pollutants
- Ground network determines area that violate standards
- Areas develop plans to meet the standards
 - Develop pollution control strategies
 - Use models to evaluate scenarios and make decisions
- Economic restrictions if fail to meet plan and standards

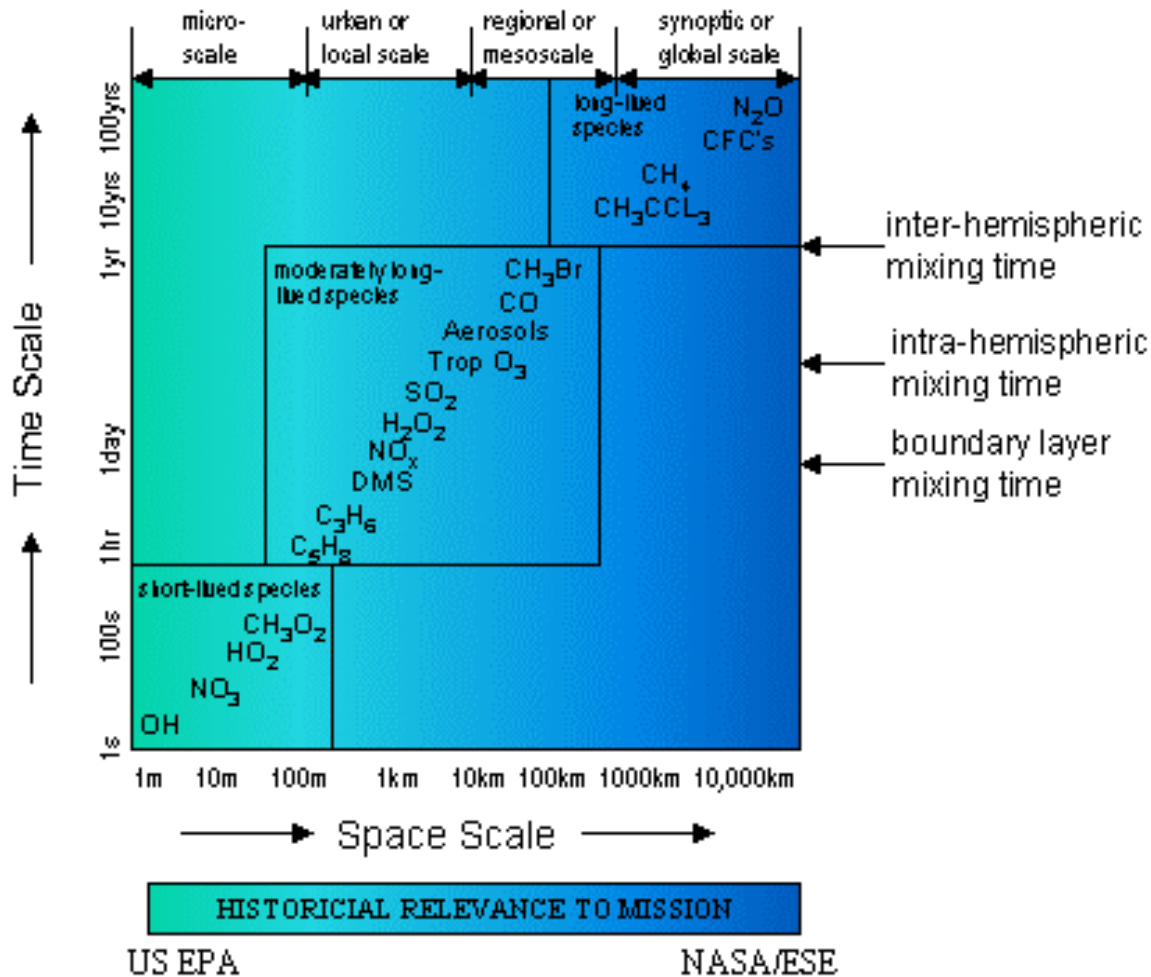
Role of Space-based Measurements in Air Quality Policy

- Coverage over vast areas & can fill-in gaps between ground monitors
- Assess global and regional transport
- Improve inventory of emissions sources for air quality models
- Provide boundary conditions for air quality models





Space in Operational & Research Agencies

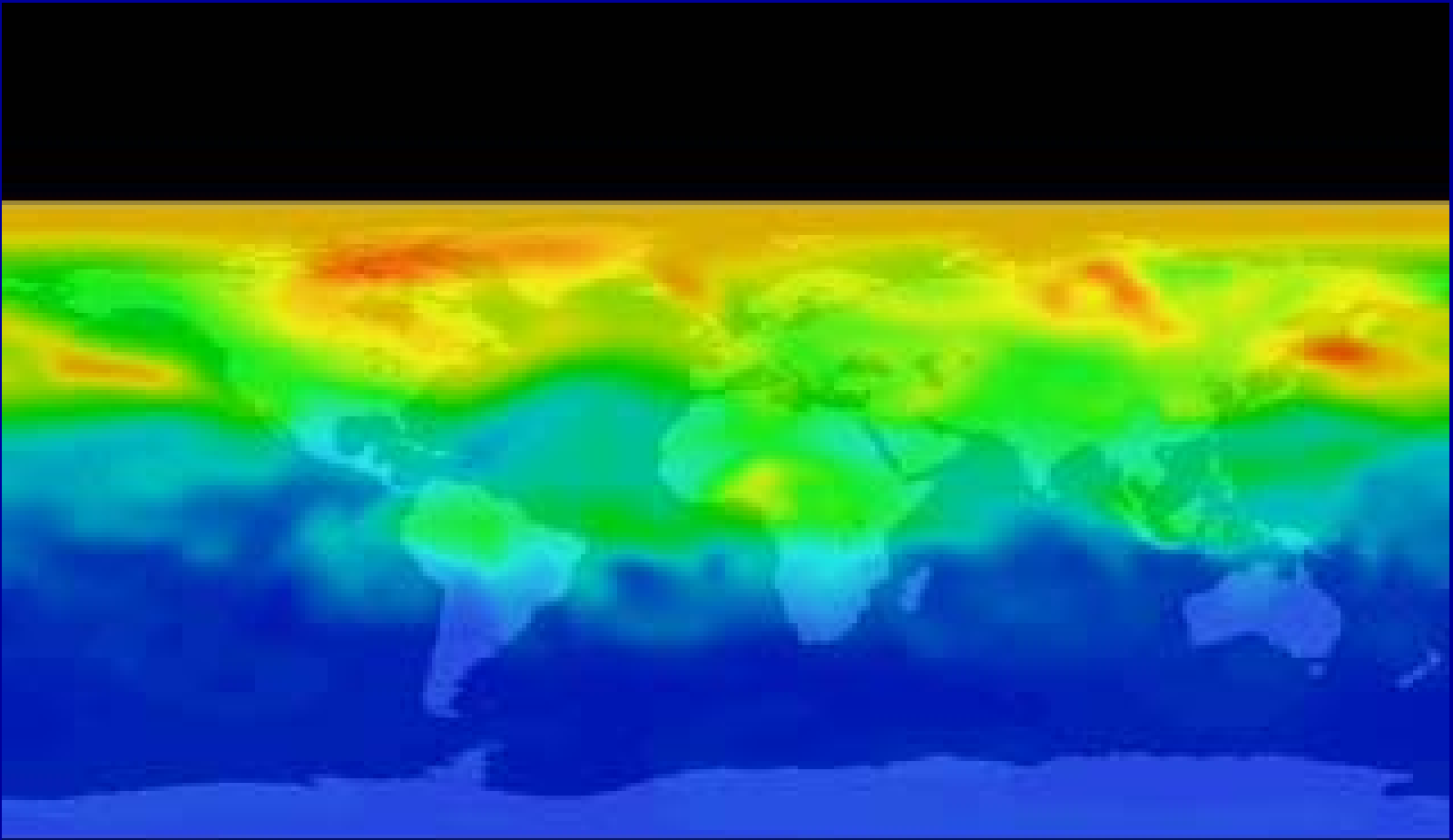


Intended application drives the focus of different agencies over spatial and temporal scales of atmospheric constituents.

*Adapted from:
National Academy of
Sciences, 1998*



Air Quality: Pollution Transport



1 Mar 2000

Global transport of carbon
monoxide in the upper troposphere.



MODELS

Chemical/Transport Models
 GISS2100
 Coupled chemistry-aerosols
 Long-range transport
 Troposphere/B.Layer Dynamics
 Others

Data

MEASUREMENTS

Aqua	Aura
Terra	SAGE III
TOMS	UARS
Calipso	SeaWiFS
QuikSCAT	TRMM
SeaWinds	GOES
GOES	EO-1
CloudSat	Aircraft

Information Products,
 Predictions, and Data
 from NASA ESE
Missions and Models:

- Trace gas concentrations
- Emissions inventories
- Boundary conditions for multi-scale models
- Fluxes of moisture & heat
- Fields of temperature & pressure
- Precipitation/rain rates
- Radiative characteristics

DECISION SUPPORT

CMAQ/Models-3
for SIP Development

Analysis:

- Assess emissions control strategies & alternatives
- Forecast long-range transport of dust/pollutants
- Prepare source emissions estimates
- Assess compliance

Management Decisions:

- Develop achievable SIPs
- Determine emission control strategy/policies
- Waivers to air standards
- Route aircraft around dust
- Warnings to farmers to mitigate impacts on crops
- Public health alerts

Additional factors:

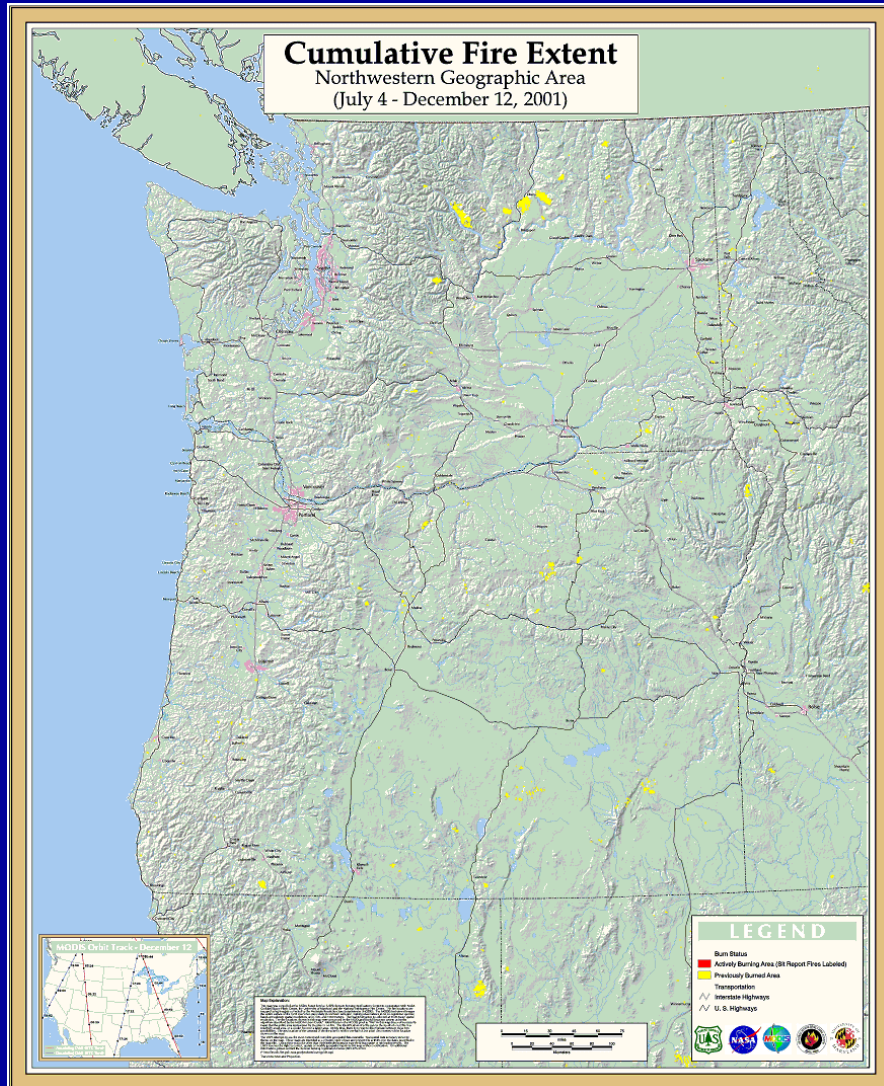
- Notices where pollutants not expected to occur

VALUE & BENEFITS

- Improve public health
- Reduce lung-related diseases & premature death
- Reduce hospital admissions & use of medicines
- Reduce lost workdays and schooldays
- Improve visibility and reduce haze for tourism
- Improve resiliency of crops; increase yields
- Increase confidence in government
- Improve crop estimates for international markets
- Reduce impaired lung-function, especially in children & elderly



Managing Wildfires



The US Forest Service has established two direct broadcast receiving installations to acquire Terra satellite data, and enable daily, near real-time distribution and decision making on allocation of fire fighting assets.



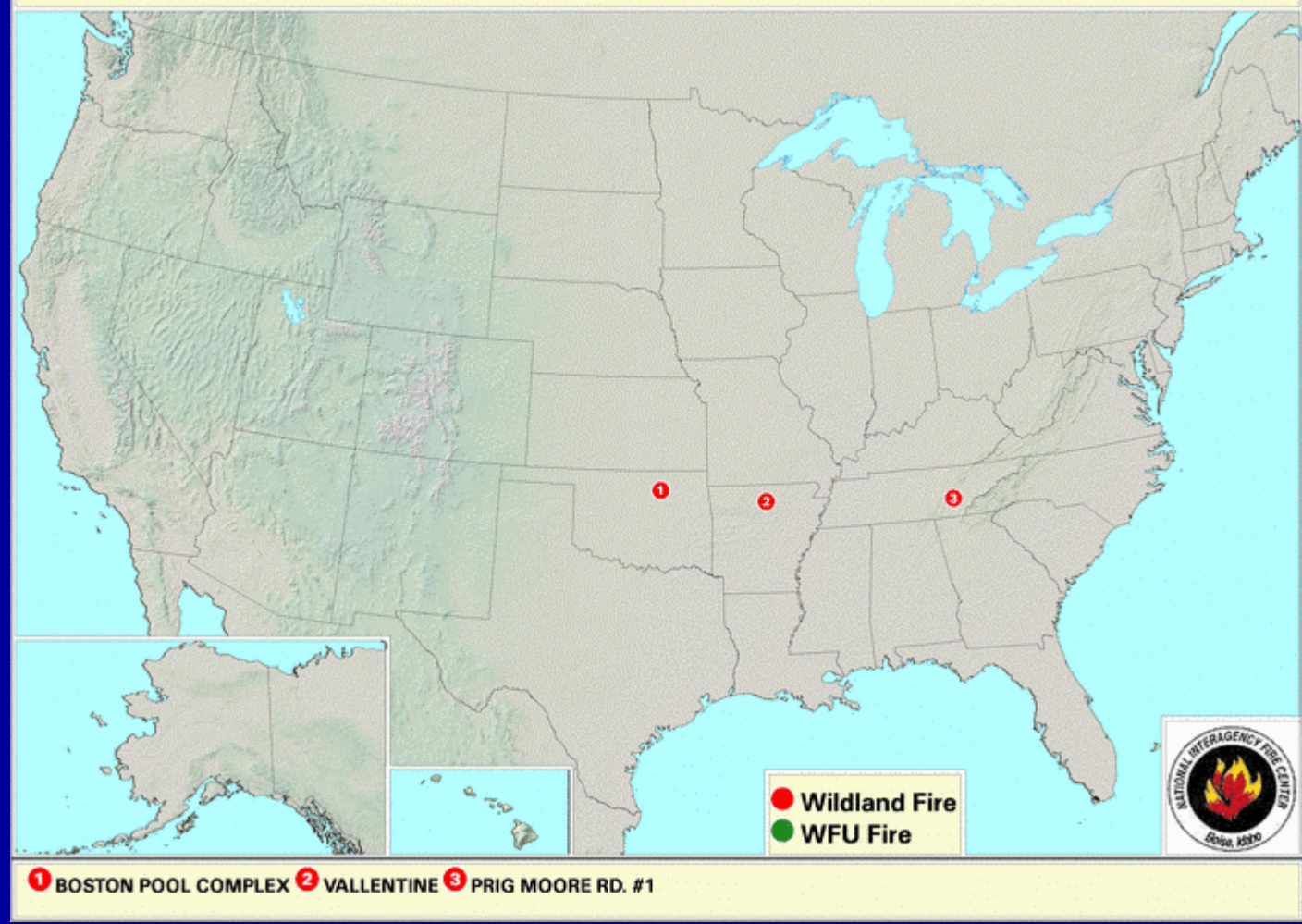


Remote Sensing
Application Center



Large Incidents - January 23, 2003

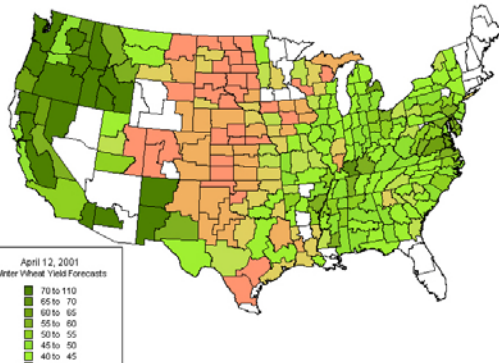
**MODIS Active
Fire Map
products (Active
Fire Maps and
Current
Detections) are
compiled daily
at 3:00 am and
3:00 pm
Mountain Time.**





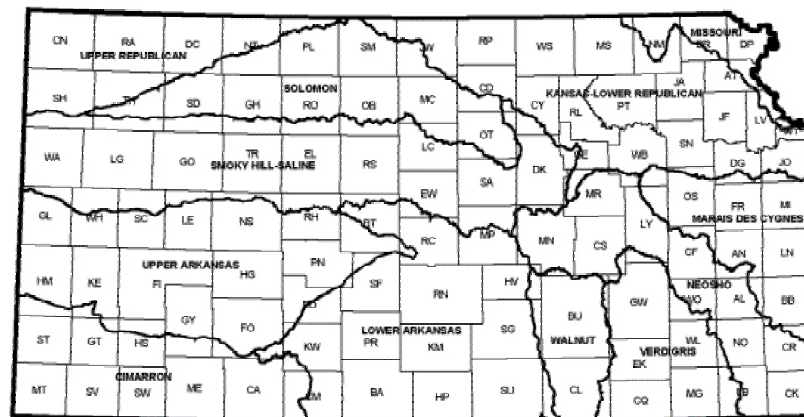
Agriculture: Improving Efficiency

Winter Wheat Yield Forecasts -- April 12, 2001
From Kansas Applied Remote Sensing Program



An applications research project with the University of Kansas has led to a new business in crop yield forecasting

Kansas Vegetation Condition Map
April 5 - August 16, 2002



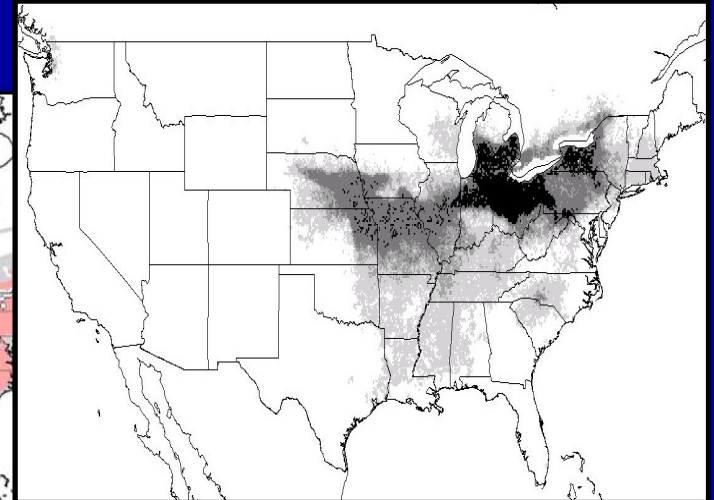
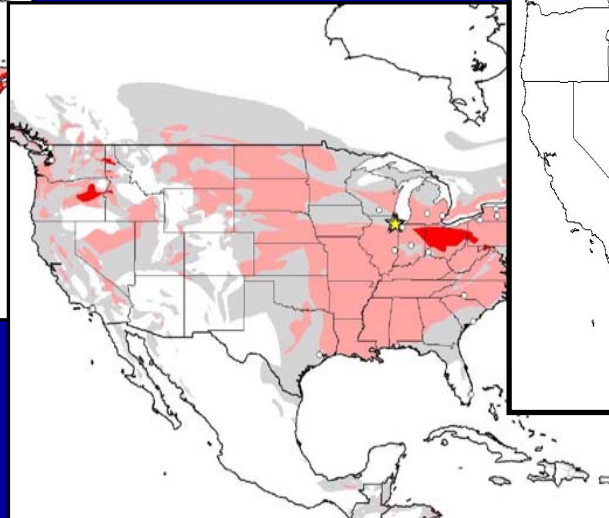
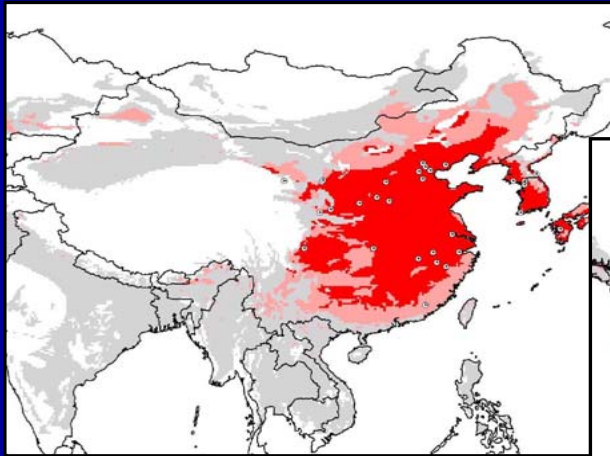
KARS
Kansas Applied Remote
Sensing Program

Vegetation Stress Poor Fair Good Condition Water

Kansas Water
Office



- Infestations discovered in Asian import warehouses
- Models of climate and habitat control in Asia
- Model climate-based potential North American spread
- Forecast narrowed based on potential habitat





Natural Hazards Management for Transportation



- **Volcanic Ash Detection:** Aircraft routing, population impacts
- **Earthquakes, soil, and Subsidence:** Road damage, Road location, expansive clay damage on roads and runways
- **Weather and Climate Change:** Hurricane Evacuation routing, snow cover, cloud cover, rainfall
- **Drought** - Areas of extended construction due to drought, water use for concrete
- **Flooding** – Road/bridge inundation and damage, traffic routing
- **Wildfires** – Smoke plumes over roadways





Major Weather Hazards

Intense severe spring and winter storms create high-impact, regionally disruptive weather

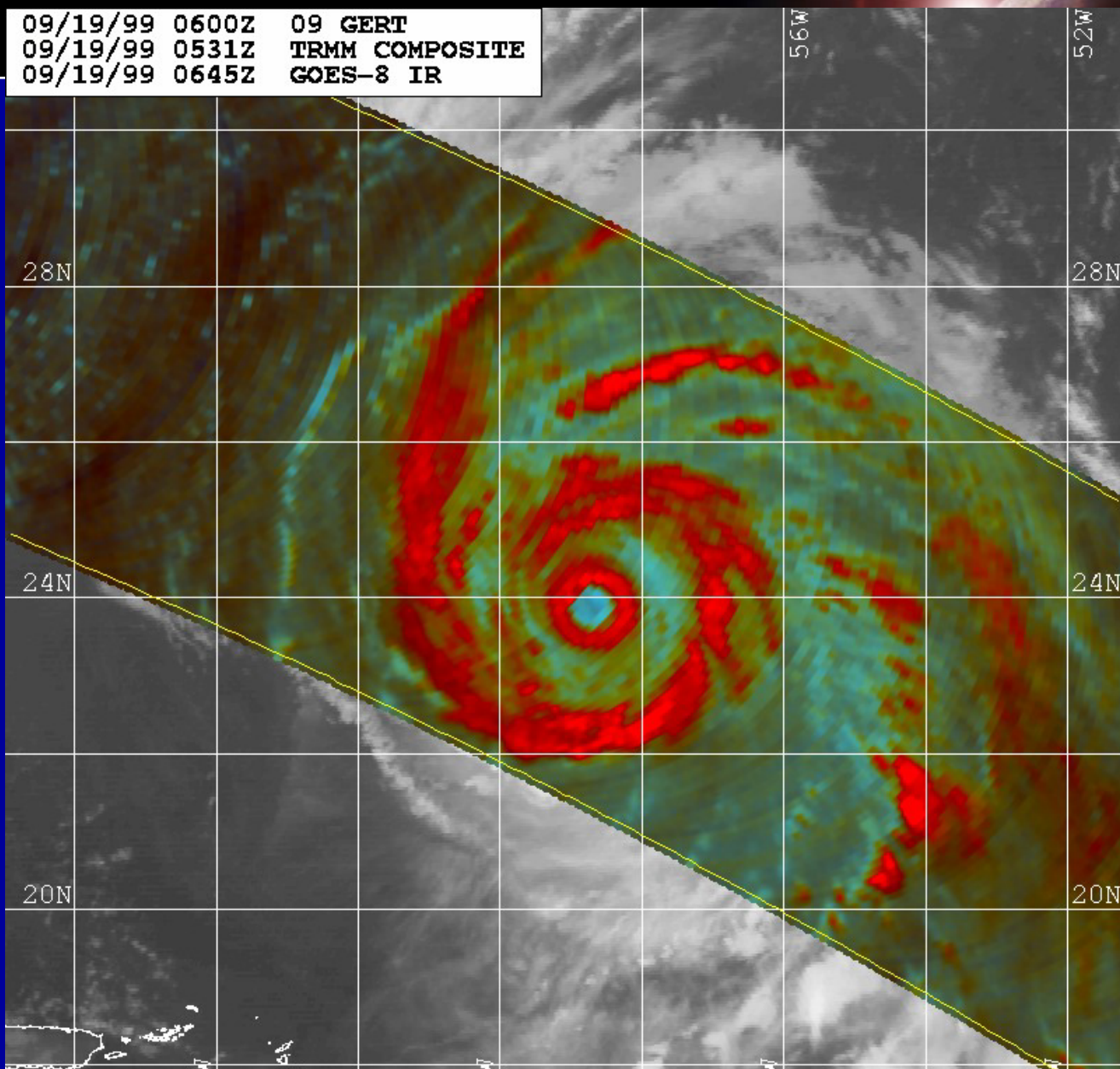




TRMM
over GOES-8 IR
TC Gert
19 Sep 1999



09/19/99 0600Z 09 GERT
09/19/99 0531Z TRMM COMPOSITE
09/19/99 0645Z GOES-8 IR



Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
Red=85PCT Green=85H Blue=85V



Inspiring the Next Generation of Explorers



- Using the Earth System Science concept to contribute to the way Earth science is taught
- Influencing each stage of the education pipeline
 - Teacher-reviewed curriculum materials for K-12; 11,438 teachers trained in 344 workshops
 - Earth System Science Education curricula for colleges & universities; implemented at 44 to date
 - Sponsoring ~150 graduate student fellowships directly, with 50 additional students selected each year
 - Sponsoring 40 early career and education grants
- Working with 25 museums to integrate NASA Earth science results into their evolving exhibits
 - Smithsonian Forces of Change Exhibit on El Nino
- Partnering with the National Park Service, the Girl Scouts, Earth & Sky Radio, and others to increase public literacy in Earth science





Learning through Telepresence

4-D Internet Visualization



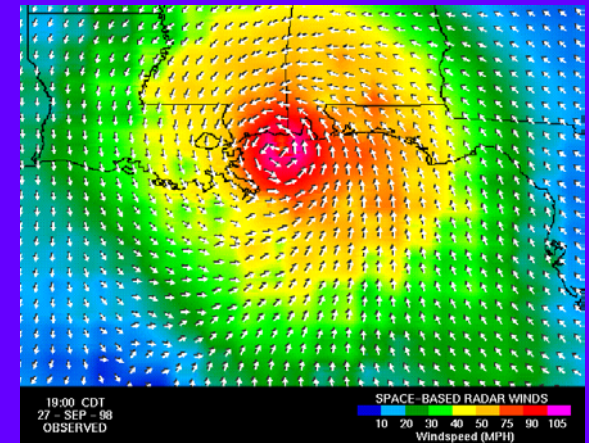
Access to continuously updated databases of Earth science data with capability to view time series

Context-Sensitive Education Modules



Access to continuously updated education modules on Earth science, remote sensing technologies, missions, models, and decision support tools

Context-Sensitive Models & Decision Support Tools



Access to continuously updated models and decision support tools for learning how to run scenarios

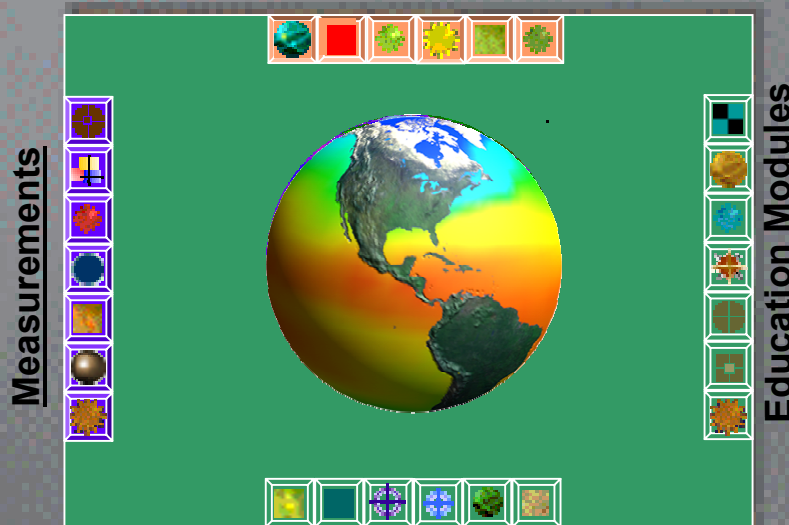


Integrated Virtual Earth System: Delivery of Science & Solutions

Science Algorithms

Land, Oceans, Ice, Atmosphere Models

Models



Decision Support Systems

FAS, CMAQ, HAZUS, EHTN, RiverWare...

Predictions and Observations

Satellite, suborbital & *in situ* observations

Data Handling Systems

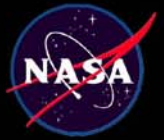
EOSDIS
DAAC
ESIP
SEEDS
...
...

Education Modules

ESSEA
ESSA21
Windows to..
WDET
...
...

Education Products

Earth Systems: *Linkages to Life on Earth*

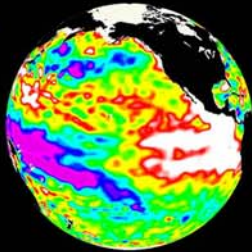


Earth Radiation Environment

Earth Magnetic Field
Orbit Dynamics
Solar Cycle / Events

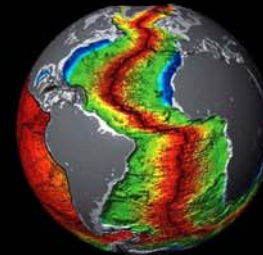
Sudden Events

Asteroid Impact
Rapid Climate
change
Volcanoes



Atmosphere - Ocean Dynamics

Weather - Storm systems
Ocean Circulation
Climate
Seasonal Variability
Greenhouse Gasses
Aerosols



Solid Earth

Earthquakes
Volcanoes
Sea Level and Global Ice



Life on Earth

Availability of Water
Hydrological Cycle
Ecosystem Health
Quality of Life

***The Reason for the End to
End Solution***



Enabling Solutions for Society

